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Floristic Composition of Vascular Epiphytes in Lambir Hills National Park, Sarawak, Malaysia in Borneo

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ABSTRACT To assess the diversity of vascular epiphytes in primary lowland mixed dipterocarp forest in Borneo, field surveys were conducted in Lambir Hills National Park, Sarawak, Malaysia in 2014–2019. A total of 183 species including 72 species of eudicots (2 species were unknown at family level) (39 %), 71 monocots (39 %), 37 pteridophytes (20 %) and 3 lycophytes (2 %), are recorded. A checklist, with voucher specimens and notes on their identification and ecological information for each species, are provided. *Dapania racemosa* Korth. (Oxalidaceae) formerly recognized as a liana, was observed as an epiphyte for the first time.

KEY WORDS canopy plants / checklist / primary lowland mixed dipterocarp forest/ plant inventory / Southeast Asia / species diversity

Introduction

Vascular epiphytes (hereinafter referred to as epiphytes) are plants growing on other plants (hosts), which are usually woody plants, or rarely herbs (Johansson 1974). They are consisted of phylogenetically various taxa, comprising 27,614 species in 913 genera in 73 families (Zotz 2013), and account for 9 % of world total vascular plant species (Madison 1977, Kress 1986, Benzing 2004). The species are diversified and abundant especially in tropical region (Richards 1964). Nadkarni et al. (2001) reported that epiphytes can even reach 10–50 percent of local flora in montane neotropical forest, and each species shows spatially complex pattern of its distribution along with various biotic or abiotic factors such as host's taxa, surface structure of substrates, and diameter of hosts, light intensity, temperature and humidity (Nieder et al. 2000, Callaway et al. 2002, Zotz & Schultz 2008, Nakanishi et al. 2016).

Generally, three types of life forms are known in epiphytes: (1) Holoepiphytes sensu Barkman (1958) are the plants grow completely without connection with ground soil throughout their lives, which includes considerable number of herbaceous epiphytes such as Orchidaceae, Bromeliaceae and Polypodiaceae, (2) Primary hemiepiphytes sensu Putz & Holbrook (1986) and Kress (1986) is the plants that start their lives as epiphytes. They germinate on host trees, meanwhile, as they grow, adventitious aerial roots down to ground soil, and then eventually, uptake water and nutrition from ground soil. Then they

grow same as general geophytes: for instance, *Philodendron* spp. (Araceae) and *Ficus* spp. (Moraceae), the latter of which is generally known as strangler figs; (3) Secondary hemiepiphytes is the plants firstly germinate on the ground, while as growing, they lose connection with the ground soil, then eventually grow as true epiphytes. *Drynaria bonii* Christ in Polypodiaceae shows this growing pattern and is classified here. Nomadic vines sensu Moffett (2000) are also sometimes regarded as hemiepiphytes, which firstly establish on the ground and lose the older main stems as the process of growing but keep connection to the ground by their roots.

Ecologically, epiphyte can be important habitat and food source for canopy organisms such as invertebrates, birds, and mammals in various ways (Nadkarni 1994, Ellwood et al. 2002, Primack & Corlett 2005, Díaz et al. 2012, Nakabayashi et al. 2016), and regarded as significant components in forest ecosystems. In fact, they play an important role as "keystone plant resources" (Nadkarni 1994).

Notwithstanding the ecological importance of epiphytes, many of basic knowledge on epiphytes are, however, remain to be explored even in its floristic inventory. The deficiency comes from mainly because of difficulty in accessing to canopy layer. Therefore, the epiphytes are absolutely under collected, and taxonomic studies based on herbarium specimens have been still insufficient. Consequently, previous studies focused on the epiphytes in tropical Southeast Asia are extremely few, compared with the studies done in other tropics in Central and South America (e.g. Nieder et al. 2000, Zotz & Schultz 2008).

To accumulate and contribute our knowledge on epiphytic flora in tropical Southeast Asia, we conducted floristic surveys focusing on epiphytes occurring from understory to canopy layer in primary lowland mixed dipterocarp forest of Lambir Hills National Park, in northern Borneo, in 2014–2019 and collected a total of 363 specimens. We here report a preliminary checklist of vascular epiphyte flora of Lambir Hills National Park, accompany with their voucher specimens, photographs, and notes on their taxonomic and ecological information.

Methods

Study site

The field surveys were conducted in Lambir Hills National Park, Sarawak, Malaysia (4°20′ N, 114°00′ E), with the elevation range from 150 to 250 m above sea level. In Lambir Hills National Park, there is no clear seasonality in environmental factors such as radiation, temperature, vapor pressure deficits, and precipitation, meanwhile, unpredictable intra-annual dry spells occur (Kumagai 2005). Many of tree species show

inconspicuous and unpredictable phenology so-called mast flowering or mast fruiting (Inoue et al. 1993, Sakai et al. 1999). In terms of vegetation type, most of area is covered with primary lowland mixed dipterocarp forest includes patches of heath forest located on ridge top, bedrock is predominantly sandstone (Lee et al. 2002, Roubik et al. 2005). The topography of Lambir is said to be "broken topography", which means showing steep slopes, sharp undulation, and complexly bisected topography (Yamakura et al. 1995). Lambir is also known as the forest which presumed to be showing highest plant species diversity in the old world (Ashton 2005). The fragmented topography as referred to above seemed to result in providing the numerous niches for various plant species and said to be the reason of high diversity. It is notable that two plots (4 ha and 8 ha, respectively) are designated as canopy biology plots and canopy facilities (canopy walk-way and canopy crane) are available for access to canopy.

Collecting and observation in the field

Canopy access was done by using canopy facilities (80 m-crane, towers with ladders and walk-ways) established in the permanent 4 ha and 8 ha plots. Ropework techniques (Perry 1978, Lowman & Schowalter 2012) were also used for accessing canopy. Epiphytes on fallen branches on the ground were also collected. All epiphyte species we observed were numbered and recorded the position where they grow on the host tree and number of individuals/populations. Voucher specimens and photographs (or sketch for particular taxa) were gathered even in sterile for each taxon, except for Orchidaceae species, the specimens of which were not collected. A small fraction of tissue was sampled with photographs from each of the observed orchid individuals as a voucher for verifying its species identification, and such sampling of the tissues was likely to have little significant negative influences on the growth and survival of each of the individuals. Hemiepiphytes, like some species of strangler figs (*Ficus* spp.) were also collected even in any life stages. However, in this study, 'nomadic vines' (Moffett 2000) were excluded because they keep connection to the ground throughout their life stages. Collecting was done by the second author during 2014–2016 and by the first author during 2016–2019. In this paper, the name of the collector was omitted.

Voucher specimens were deposited at the herbaria of Forest Herbarium (SAR), Kuching.

Identification

To identify species, we examined herbarium specimens at Forest Herbarium (SAR), Kuching, the Herbarium of Japanese Laboratory of Lambir Hills National Park, the herbarium of the Kyoto University Museum (KYO). We also examined specimen images on the web (e.g. JSTOR Global Plant Science 2019), as well as the taxonomic literature on particular groups: *Amomum roseisquamosum* (Zingiberaceae, Nagamasu & Sakai 1996), *Scindapsus* spp. (Araceae, Othman et al. 2010, Saibeh et al. 2015), Davalliaceae

(Kato & Tsutsumi 2008, Lindsay & Middleton 2012), Polypodiaceae (Ebihara et al. 2008, Lindsay & Middleton 2012), *Asplenium nidus* (Aspleniaceae, Holltum 1974), *Embelia* spp. (Primulaceae, Dubéarnès et al. 2015), *Ficus* spp. (Moraceae, Kochummen 2000, Harrison et al. 2003), *Hoya* spp. (Apocynaceae, Lamb & Rodda 2016), and *Pachycentria* spp. (Melastomataceae, Clausing 2000).

Families and species of angiosperms were arranged in classification in accordance with Angiosperm Phylogeny Group (APG) IV (Angiosperm Phylogeny Group 2016) for seed plants. For pteridophytes, we apply the family and genus concepts summarized by Smith et al. (2006, 2008) and Lindsay et al. (2009).

Flowering and fruiting characters are important to identify plants at species level. However, most of our collections were in sterile (vegetative states). We temporarily identified these species only at genus or family levels. Among these, we used DNA barcoding of *rbcL* and *matK* regions for some taxa which could not identify the family or genus in the field. DNA extraction, amplification, and sequencing were performed in accordance with the published protocols (Kress et al. 2009, Dunning & Savolainen 2010).

Results

A total of 364 specimens, consisted of 183 epiphyte species in 64 genera and 24 families and 2 species unknown even in family, were confirmed with sampling or observation from our field surveys in 4 ha and 8 ha plots and their vicinities in Lambir Hills National Park. Those were confirmed from tree trunk and branches of 98 trees (52 species in 30 families) or found on fallen trunk and branches in understory. Eudicots were represented by 11 families (2 species were unknown at family level) with 72 species (40.4 %). Monocots were represented by 4 families with 71 species (38.7 %), pteridophytes were represented by 8 families with 37 species (20.2 %), and lycophytes were represented by 1 family with 3 species (1.6 %). Family-level species richness was highest in Orchidaceae with 54 species (29.5 % of total number of species), followed by Apocynaceae (23 spp. (12.6 %)), Moraceae (21 spp. (11.4 %)), Polypodiaceae (16 spp. (8.74 %)), and Araceae (11 spp. (6.0 %)).

Checklist

LYCOPHYTA

Huperziaceae

Huperzia carinata (Desv. ex Poir.) Trevis., Atti Soc. Ital. Sci. Nat. 17: 247 (1874). Fig.1A–1C.

Specimen ID. *C72, C75, LCV29, LCV143*.

Notes. Stem pendent down to 50 cm long; usually grows on canopy humus on Dipterocarpaceae trees; found from 8 ha plot.

Huperzia nummulariifolia (Blume) Jermy, Brit. Fern Gaz. 10(4): 176 (1971). Fig.1D.

Specimen ID. *LCV192.*

Notes. Distinguished from the other two *Huperzia* species by its having round-tipped lamina; found on canopy humus; collected from 4 ha and 8 ha plots; rare.

Huperzia phlegmaria (L.) Rothm., Feddes Repert. Spec. Nov. Regni Veg. 54: 62 (1944). Fig.1E & 1F.

Specimen ID. *C95, LCV89, LCV233*.

PTERIDOPHYTA

Aspleniaceae

Asplenium auriculatum Sw., Kongl. Vetensk. Acad. Handl. 1817(1): 68 (1817). Fig.2A–2C.

Specimen ID. *C113, C119, LCV96*.

Asplenium nidus L., Sp. Pl. 2: 1079 (1753). Fig.2D–2F.

Specimen ID. *LCV33*.

Notes. Large bird-nest fern, with diameter to ca. 200 cm. Lamina brownish green and entire midrib blackish abaxially *in sicco*; found in 4 ha and 8 ha plots; common.

Asplenium sp. 1.

Specimen ID. *LCV52*.

Notes. Large bird-nest fern. Lamina yellowish brown *in sicco*. Abaxial surface of midrib entirely pale brown *in sicco*; collected from 8 ha plot.

Asplenium sp. 2.

Specimen ID. *LCV59*.

Notes. Large bird nest fern; lamina grayish green *in sicco*. Abaxial surface of midrib blackish brown at lower part, grayish green at upper part *in sicco*.

Asplenium sp. 3.

Specimen ID. *LCV317*.

Notes. Characterized by lamina of less than 10 cm in width; found on a trunk of small tree, about 2 m high from the ground.

Davalliaceae

Davallia denticulata (Burm.) Mett. & Kuhn, Fil. Deck. 27 (1867). Fig.3A–3C.

Specimen ID. *C77, C111, LCV82, LCV214*.

Davallia solida (Forst.) Sw., J. Bot. (Schrader) 1800(2): 87 (1801). Fig.3D & 3E.

Specimen ID. *LCV16*.

Notes. Leaves thickly coriaceous; found only from the top of tree near Tower 1 in 8 ha plot; rare.

Davallia sp. Fig.3F & 3G.

Specimen ID. *LCV205, LCV297*.

Notes. Leaves simple and coriaceous. Rhizomes flattened and covered with blackish trichomes; common in semi-shaded branches in 4 ha plot.

Humata angustata J. Sm., J. Bot. (Hooker) 3: 415, 416 (1841).
Specimen ID. LCV359.
Notes. Characterized by simple and coriaceous leaves; found on a tree trunk, at 1 m height from the ground; in forest edge along streams.
Humata repens (L.f.) Diels., Nat. Pflanzenfam. 1(4): 209 (1899). Fig.3H–3J.
Specimen ID. LCV372.

Dryopteridaceae

Elaphoglossum sp. Fig.4A–4C.
Specimen ID. LCV364.
Notes. Rhizomes short-creeping; collected from lower part of a small tree in a gap near a stream.

Hymenophyllaceae

Hymenophyllum sp. 1.
Specimen ID. LCV71.
Notes. Collected from lower trunk of large tree; found from 8 ha plot; rare.
Hymenophyllum sp. 2. Fig.4D & 4E.
Specimen ID. LCV365.
Notes. Collected from lower trunk of a small tree. Near a stream; rare.
Hymenophyllum sp. 3. Fig.4F & 4G.
Specimen ID. LCV366.
Notes. Collected from lower trunk of a small tree. Near a stream; rare.

Lomariopsidaceae

Nephrolepis sp. Fig.4H & 4I.
Specimen ID. LCV180, LCV292.

Ophioglossaceae

Ophioglossum pendulum L., Sp. Pl. ed. 2: 1518 (1763). Fig.4J & 4K.
Specimen ID. LCV350.

Polypodiaceae

Aglaomorpha speciosa (Blume) M.C. Roos, Phylogen. Syst. Dryn.: 244 (1985).
Specimen ID. C88, C89, C104, LCV114.
Drynaria quercifolia (L.) J. Sm., J. Bot. (Hooker) 3: 398 (1841). Fig.5A & 5B.
Specimen ID. LCV53, LCV93.
Drynaria sparsisora (Desv.) T. Moore, Index Fil.: 348 (1862). Fig.5C & 5D.
Specimen ID. C80, LCV9, LCV57, LCV97, LCV148, LCV222.
Goniophlebium percussum (Cav.) Wagner & Grether, Occas. Pap. Bernice Pauahi Bishop Mus. 19: 88 (1948). Fig.5E–5H.
Specimen ID. LCV18, LCV130, LCV349.

Lecanopteris sinuosa (Hook.) Copel., Univ. Calif. Publ. Bot. 16: 123 (1929).
Specimen ID. C46.
Lecanopteris sp. Fig.5I.
No sample.
Notes. A myrmecophytic fern; grows on emergent *Shorea* trees (Dipterocarpaceae), and usually observed with *Platycerium ridleyi*.
Leptochilus macrophyllus (Blume) Noot., Blumea 42(2): 286 (1997).
Specimen ID. LCV242.
Microsorum punctatum (L.) Copel., Univ. Calif. Publ. Bot. 16(2): 111 (1929).
Specimen ID. LCV272.
Phymatosorus scolopendria (Burm. f.) Pic. Serm., Webbia 28(2): 457, 460 (1973).
Specimen ID. LCV134, LCV135.
Notes. Leaf shape variable, from simple to 3-lobed; collected only from 8 ha plot; rare.
Platycerium coronarium (O.F. Müll.) Desv., Mém. Soc. Linn. Paris 6: 213 (1827). Fig.6A & 6B.
Specimen ID. C40.
Platycerium ridleyi Christ, Ann. Jard. Bot. Buitenzorg Suppl. 3: 8 (1909). Fig.6C.
Specimen ID. LCV128.
Notes. A myrmecophytic fern with large domatia; grows on semi-shaded parts of emergent trees of *Shorea* spp.
Pyrrosia angustata (Sw.) Ching, Bull. Chin. Bot. Soc. 1(1): 49 (1935). Fig.6D–6F.
Specimen ID. C59, LCV46, LCV361.
Pyrrosia longifolia (Burm. f.) C.V. Morton, J. Wash. Acad. Sci. 36(5): 168 (1946).
Specimen ID. LCV284.
Pyrrosia sp. 1.
Specimen ID. LCV250.
Pyrrosia sp. 2.
Specimen ID. LCV14, LCV252.
Selliguea sp. 1.
Specimen ID. LCV360.

Pteridaceae

Antrophyum sp. 1.
Specimen ID. LCV70.
Antrophyum sp. 2.
No sample.
Notes. Leaves thickly coriaceous, dark blue in color; found from small tree in a gap near a stream.
Haplopteris angustifolia (Blume) E.H. Crane, Syst. Bot. 22(3): 514 (1997). Fig.6G–6I.
Specimen ID. LCV58, LCV211.
Haplopteris ensiformis (Sw.) E.H. Crane, Syst. Bot. 22(3): 514 (1997).
Specimen ID. C55, C108, LCV1, LCV11, LCV184, LCV220, LCV225, LCV236.
Haplopteris sp.
Specimen ID. LCV299.

MONOCOTYLEDONEAE

Araceae

Amydrium medium (Zoll. & Moritzi) Nicolson, Blumea 16: 124 (1968). Fig.7A & 7B.
Specimen ID. LCV333.
Notes. Common in understory, usually as a nomadic vine but sometimes grows as an epiphyte on basal part of large tree trunk.

Epipremnum sp.
Specimen ID. LCV255.

Rhaphidophora tenuis Engl., Bot. Jahrb. Syst. 1(2): 181 (1880). Fig.7C & 7D.
Specimen ID. LCV332.
Notes. Usually grow as a nomadic vine, but sometimes grow as an epiphyte on humus deposited at the base of large tree trunks.

Scindapsus beccarii Engl., Bot. Jahrb. Syst. 1(2): 182 (1880). Fig.7E–7G.
Specimen ID. LCV191, LCV199.

Scindapsus coriaceus Engl., Bull. Reale Soc. Tosc. Ortic. 4: 271 (1879). Fig.7H & 7I.
Specimen ID. LCV176, LCV198, LCV239.
Notes. Creeping robust epiphyte; grows on large Dipterocarpaceae trees; common in 4 ha and 8 ha plots.

Scindapsus cf. *glaucescens* (Engl. & K. Krause) Alderw., Bull. Jard. Bot. Buitenzorg 1: 387 (1920).
Specimen ID. LCV314.

Scindapsus pictus Hassk., Hoev. & De Vriese, Tijdschr. Natuurl. Gesch. Physiol. 9: 164 (1842).
Specimen ID. LCV68.

Scindapsus treubii Engl., Bot. Jahrb. Syst. 25: 13 (1898).
Specimen ID. LCV329.

Scindapsus sp. 1. [aff. *coriaceus* Engl., Bull. Reale Soc. Tosc. Ortic. 4: 271 (1879).]
Specimen ID. LCV122.
Notes. Creeping epiphyte; leaves narrowly lanceolate.

Scindapsus sp. 2.
Specimen ID. LCV310.

Scindapsus sp. 3.
Specimen ID. LCV121, LCV171, LCV187.
Notes. Creeping herb with coriaceous leaves; grows on canopy humus on large trees.

Orchidaceae

Appendicula sp. 1.
Voucher tissue sample ID. LCV358.
Notes. Leaves purple; found in riverine forest; rare.

Bromheadia cf. *truncata* Seidenf., Opera Bot. 72: 14 (1983).
Voucher tissue sample ID. C44, C45, LCV228, LCV235, LCV306.

Bromheadia sp. 1.
Voucher tissue sample ID. LCV307.

Notes. Collected from a community of *Bromheadia* cf. *truncata* on large *Shorea kunstleri* King.

Bromheadia sp. 2.

Voucher tissue sample ID. LCV363.

Bulbophyllum auratum (Lindl.) Ridl., Mat. Fl. Malay. Penins. 1: 82 (1907). Fig.8A–8C.

Voucher tissue sample ID. LCV45, LCV196.

Bulbophyllum limbatum Lindl., Edwards's Bot. Reg. 26: 74 (1840). Fig.8D & 8E.

Voucher tissue sample ID. C41, C47, LCV241.

Notes. Characterized by long rhizome, dark red perianth; common in semi-shaded crown of canopy tree in 4 ha plot.

Bulbophyllum vaginatum Rchb. f., Ann. Bot. Syst. 6: 261 (1864). Fig.8F & 8G.

Voucher tissue sample ID. C57, LCV10, LCV158.

Bulbophyllum sp. 1.

No sample

Notes. On a trunk of a fallen tree in 8 ha; rare.

Bulbophyllum sp. 2.

Voucher tissue sample ID. LCV141, LCV218.

Notes. Similar to *B. auratum* but can be distinguished by longer rhizomes between bulbs.

Bulbophyllum sp. 3.

Voucher tissue sample ID. C81, C83, LCV86.

Notes. Bulbs small and not swollen.

Bulbophyllum sp. 4.

Voucher tissue sample ID. LCV109, LCV110.

Notes. Bulbs and leaves purplish-green, rhizomes very short.

Bulbophyllum sp. 5.

Voucher tissue sample ID. LCV261.

Bulbophyllum sp. 6.

Voucher tissue sample ID. LCV267.

Notes. Rhizomes long and brown; found in 4 ha plot; common.

Bulbophyllum sp. 7.

Voucher tissue sample ID. LCV367.

Notes. Collected from lower trunk of small tree; in a gap near a stream.

Coelogyne foerstermannii Rchb.f., Gard. Chron., n.s. 26: 262–263 (1886). Fig.8H & 8I.

Voucher tissue sample ID. C42, C66, LCV234.

Notes. A robust orchid with highly succulent pseudobulbs; fairly common in both 4 ha and 8 ha plots.

Coelogyne sp. 1.

Voucher tissue sample ID. LCV107.

Coelogyne sp. 2.

Voucher tissue sample ID. LCV270.

Cymbidium finleysonianum Wall. ex Lindl., Gen. Sp. Orchid. Pl.: 164 (1833).

Voucher tissue sample ID. LCV126, LCV131, LCV188.

Dendrobium aloifolium (Blume) Rchb.f., Ann. Bot. Syst. 6: 279 (1861).

Voucher tissue sample ID. LCV111.

Dendrobium crumenatum Sw., J. Bot. (Schrader) 2: 237 (1799)

No sample

Dendrobium grootingsii J.J. Sm., Bull. Jard. Bot. Buitenzorg, sér. 2, 25: 33 (1917).
Voucher tissue sample ID. C84, C87, LCV4, LCV91.
Dendrobium leonis Rchb. f., Ann. Bot. Syst. 6: 280 (1864). Fig.9A.
Voucher tissue sample ID. C43, C62, LCV31, LCV84.
Dendrobium pinifolium Ridl., J. Linn. Soc., Bot. 31: 269 (1896). Fig.9B & 9C.
Voucher tissue sample ID. LCV201, LCV230.
Dendrobium cf. *hymenanthum* Rchb. f., Bonplandia 3: 222 (1855).
Voucher tissue sample ID. LCV312.
Dendrobium cf. *truncatum* Lindl., J. Proc. Linn. Soc., Bot. 3: 15 (1858).
Voucher tissue sample ID. LCV298.
Dendrobium sp. 1.
Voucher tissue sample ID. LCV323.
Dendrobium sp. 2.
Voucher tissue sample ID. LCV295.
Dendrobium sp. 3.
Voucher tissue sample ID. LCV262.
Dendrobium sp. 4.
Voucher tissue sample ID. LCV322.
Dendrobium sp. 5.
Voucher tissue sample ID. LCV42, LCV56.
Dendrochilum sp. 1.
Voucher tissue sample ID. LCV226.
Diplocaulobium cf. *brevicolle* (J.J. Sm.) Kraenzl., Pflanzenr.: 335 (1910).
Voucher tissue sample ID. LCV238.
Dipodium sp. 1.
Voucher tissue sample ID. LCV245.
Eria leiophylla Lndl., J. Proc. Linn. Soc., Bot. 3: 57 (1858). Fig.9D.
Voucher tissue sample ID. LCV115.
Eria pannea Lindl., Edwards's Bot. Reg. 28: 64 (1842). Fig.9E & 9F.
Voucher tissue sample ID. C63, LCV40, LCV108.
Eria sp. 1.
Voucher tissue sample ID. LCV43.
Eria sp. 2.
Voucher tissue sample ID. C61, C67, LCV48.
Eria sp. 3.
Voucher tissue sample ID. LCV190, LCV244.
Eria sp. 4.
Voucher tissue sample ID. C56, LCV247.
Eria sp. 5.
Voucher tissue sample ID. LCV229.
Eria sp. 6.
Voucher tissue sample ID. LCV343.
Eria sp. 7.
Voucher tissue sample ID. LCV129.
Liparis grandiflora Ridl., J. Bot. 22: 333 (1884).

Voucher tissue sample ID. LCV300.

Liparis sp. 1.

Voucher tissue sample ID. LCV266.

Liparis sp. 2.

Voucher tissue sample ID. LCV319.

Luisia sp. 1.

Voucher tissue sample ID. C93, LCV80, LCV90.

Phalaenopsis cornu-cervi (Hasselt ex Hassk.) Blume & Rchb. f., Hamburger Garten-Blumenzeitung 16: 116 (1860). Fig.9G & 9H.

No sample

Notes. Flowering individuals were observed and identified.

Podochilus sp. 1.

Voucher tissue sample ID. LCV369.

Rhynchostylis sp. 1.

Voucher tissue sample ID. C90-1, C90-2, LCV7.

Rhynchostylis sp. 2.

Voucher tissue sample ID. C64.

Thrixspermum sp. 1.

Voucher tissue sample ID. LCV243.

Trichotosia cf. *ferox* (Blume) Korth. ex Blume, Mus. Bot. 2: 184 (1856).

Voucher tissue sample ID. LCV27, LCV100.

Vanda sp. 1.

Voucher tissue sample ID. LCV139.

Vanda sp. 2.

Voucher tissue sample ID. LCV102.

Pandanaceae

Benstonea sp. Fig.10A.

No sample.

Notes. A robust rosette-shaped epiphyte; usually grows on large tree folks.

Freycinetia sp. 1. Fig.10B & 10C.

Specimen ID. LCV326.

Notes. Leaf margin dentate; primary hemiepiphyte, initially established on basal trunk of trees.

Freycinetia sp. 2.

Specimen ID. LCV327.

Notes. Leaf margin entire; primary hemiepiphyte, initially established on basal trunk of trees.

Zingiberaceae

Amomum roseisquamosum Nagam. & S. Sakai, Edinburgh J. Bot. 53(1): 39 (1996). Fig.10D & 10E.

Specimen ID. LCV223.

Notes. Characterized by its pink bracts and white flowers; endemic to Lambir; rather common.

Globba sp. 1.
Specimen ID. *C35*.
Globba sp. 2.
Specimen ID. *LCV275*.

EUDICOTYLEDONEAE

Apocynaceae

Dischidia cochleata Blume, Bijdr., Fl. Ned. Ind. 16: 1060 (1827). Fig.11A & 11B.
Specimen ID. *C50, LCV259*.
Notes. A myrmecophytic species, with ragged adaxial leaf surface; common on exposed branches of *Shorea beccariana* Burck.; in 4 ha plot.
Dischidia hirsuta (Blume) Decne., Prodr. [A.P. de Candolle] 8: 632 (1844). Fig.11C.
Sp*ecimen ID*. *C91, LCV142, LCV204*.
Notes. Characterized by hirsute leaves, adaxially prominent midrib and but secondary veins, and reddish corolla; in 4 ha and 8 ha plots; common.
Dischidia major (Vahl) Merr., Interpr. Herb. Amboin.: 437 (1917). Fig.11D.
Specimen ID. *LCV49*.
Dischidia cf. *nummularia* R.Br., Prodr. Fl. Nov. Holland.: 461 (1810).
Specimen ID. *C8*.
Dischidia sp. 1.
Specimen ID. *LCV177*.
Notes. Distinguished by highly succulent stems, which are almost without leaves; in 4 ha and 8 ha plots; common.
Dischidia sp. 2. Fig.11E–11G.
Specimen ID. *LCV291*.
Notes. Characterized by ca. 2 cm long lamina which abaxial surface is pale green, and 5 mm long corolla which lower half is reddish and upper pale yellow.
Dischidia sp. 3. Fig.11H & 11I.
Specimen ID. *C31*.
Notes. Leaves forming saccate domatia; found from 4 ha plot; rare.
Dischidia sp. 4.
Specimen ID. *C51*.
Notes. Lamina circular, and smooth on adaxial surface; probably myrmecophytic.
Dischidia sp. 5.
Specimen ID. *LCV296*.
Notes. Lamina 1.2 cm long, and densely ragged on adaxial leaf surface.
Dischidia sp. 6.
Specimen ID. *LCV362*.
Notes. Characterized by densely ragged adaxial leaf surface, rose pink calyx and pale pink corolla.
Dischidia sp. 7.
Specimen ID. *LCV305, LCV330*.

Notes. Plants entirely glabrous, and pale green. Leaves slightly peltate.

Dischidia sp. 8. Fig.11J.

Specimen ID. LCV318.

Notes. Leaves narrowly ovate to lanceolate; aerial roots forms spherical clusters (ca. 5 cm in diameter); found on a small tree; rare.

Hoya cf. *finleysonii* Wight, Contr. Bot. India (Wight): 38 (1834).

Specimen ID. LCV179, LCV271, LCV274.

Notes. Leaves 17 cm long, secondly veins conspicuously visible *in vivo*.

Hoya lacunosa Blume, Bijdr. Fl. Ned. Ind. 16: 1063 (1827). Fig.12A & 12B.

Specimen ID. LCV269.

Notes. Lamina ovate shape with cuspidate apex.

Hoya cf. *mappigera* Rodda & Simonsson, Feddes Repert. 122(5–6): 338 (2012).

Specimen ID. LCV60.

Notes. Scandent shrub with oblong and thinly coriaceous leaves; so far only found from a single *Shorea* tree in 8 ha; rare.

Hoya mitrata Kerr, Hooker's Icon. Pl. 35: t. 3406 (1940). Fig.12C–12E.

Specimen ID. LCV303, LCV386.

Notes. Lamina cordate at base. Leaves on lower shoot form domatia; rare.

Hoya cf. *sigillatis* T. Green, Fraterna 17(3): 2 (2004). Fig.12F & 12G.

Specimen ID. LCV260.

Notes. Lamina mottled with white blotches, and asperous adaxially.

Hoya sp. 1.

Specimen ID. LCV5.

Hoya sp. 2.

Specimen ID. LCV193.

Hoya sp. 3.

Specimen ID. LCV249.

Hoya sp. 4.

Specimen ID. LCV175.

Notes. Lamina narrowly elliptic, 10 cm long.

Hoya sp. 5.

Specimen ID. LCV342.

Notes. Lamina oblong, 10–15 cm long.

Hoya sp. 6.

Specimen ID. LCV276, LCV313, LCV341.

Notes. Lamina elliptic, 5 cm long, midrib prominent on adaxial surface.

Araliaceae

Schefflera littoralis (Miq.) Harms., Nat. Pflanzenfam. (Engler & Prantl) 3(8): 38 (1894). Fig.13A–13C.

Specimen ID. C92, LCV92, LCV105.

Notes. Leaf yellowish green, margin weakly dentate; found in 8 ha plot; common.

Schefflera sp.

Specimen ID. LCV287.

Ericaceae

Vaccinium sp. Fig.13D–13F.
Specimen ID. *LCV32*.
Notes. Shrub with slightly tuberous roots and often pendent branches; collected from 4 ha plot; rather common; identified by DNA sequencing.

Gentianaceae

Fagraea ceilanica Thunb., Kongl. Vetensk. Acad. Nya Handl. 3: 132 (1782). Fig.14A & 14B.
Specimen ID. *LCV353.*
Notes. Petioles and twigs greenish brown; scandent shrub to tree, sometimes hemiepiphyte.
Fagraea ridleyi King & Gamble, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74(2): 612 (1908). Fig.14C & 14D.
Specimen ID. *LCV249-2, LCV301*.
Fagraea rugulosa K.M.Wong & Sugau, Sandakania 8: 22 (1996).
Specimen ID. *LCV221*.

Gesneriaceae

Aeschynanthus angustifolius (Blume) Steud., Nomencl. Bot. ed. 2(1): 32 (1840). Fig.14E–14G.
Specimen ID. *LCV315*.
Notes. Small shrub; lamina linear and slightly succulent; rare.
Aeschynanthus tricolor Hook., Bot. Mag. 84: t. 5031 (1858). Fig.14H & 14I.
Specimen ID. *LCV337*.
Notes. Calyx red, corolla dark red; found in riverine forest; rare.

Melastomataceae

Heteroblemma sp. Fig.15A.
Specimen ID. *LCV352*.
Notes. Woody creeper; collected from a decaying trunk or lower tree trunks.
Pachycentria constricta Blume, Flora 14: 520 (1831). Fig.15B.
Specimen ID. *LCV182, LCV344*.
Notes. Shrub, with roots forming fusiform tubers; common.
Pachycentria glauca Triana, Trans. Linn. Soc. London 28(1): 89 (1871). Fig.15C & 15D.
Specimen ID. *C48, LCV331*.
Notes. Small shrub, with roots forming round tubers.
Pachycentria pulverulenta (Jack) G. Clausing, Blumea 45(2): 362 (2000).
Specimen ID. *LCV88, LCV170, LCV197, LCV227*.
Notes. Scandent shrub, with roots not forming tubers.
Pachycentria sp. 1. Fig.15E.
Specimen ID. *LCV336*.
Pachycentria sp. 2.
Specimen ID. *LCV183, LCV232, LCV334*.

Plethiandra tomentosa G. Kadereit, Edinburgh J. Bot. 62(3): 141 (2006). Fig.15F & 15G.
Specimen ID. *LCV308, LCV400*.
Notes. Creeping to scandent shrub; found on large tree in riverine forest; common.

Moraceae

Ficus aurantiaca Miq., Ann. Mus. Bot. Lugduno-Batavi 3: 293 (1867). Fig.16A.
Specimen ID. *LCV347*.
Notes. Epiphytic on basal part of tree trunk when juvenile stage, then grows as a terrestrial liana.
Ficus binnendijkii Miq. var. *latifolia* Corner, Gard. Bull. Singapore 17: 395 (1960).
Specimen ID. *C71, LCV24, LCV185*.
Ficus deltoidea Jack, Malayan Misc. 2(7): 71 (1822). Fig.16B & 16C.
Specimen ID. *LCV189, LCV356*.
Ficus dubia Wall. ex King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 56(1): 46 (1887). Fig.16D–16F.
Specimen ID. *LCV125, LCV397*.
Ficus kerkhovenii Koord. & Valeton, Meded. Dept. Landb. Ned.-Indië 2: 83 (1906).
No sample.
Notes. listed and identified based on the specimen stocked in the Herbarium of Japanese laboratory in Lambir Hills National Park.
Ficus parietalis Blume, Bijdr. Fl. Ned. Ind. 9: 462 (1825).
Specimen ID. *LCV340*.
Ficus pisocarpa Blume, Bijdr. Fl. Ned. Ind. 9: 454 (1825).
Specimen ID. *LCV13*.
Ficus punctata Lam., Encycl. [J. Lamarck et al.] 2(2): 495 (1788).
Specimen ID. *LCV346*.
Ficus stricta Miq., Ann. Mus. Bot. Lugduno-Batavi 3: 266 (1867).
Specimen ID. *LCV20, LCV23, LCV95, LCV281*.
Ficus stupenda Miq., Ann. Mus. Bot. Lugduno-Batavi 3: 286 (1867).
Specimen ID. *LCV302*.
Ficus subgelderi Corner, Gard. Bull. Singapore 17: 386 (1960).
Specimen ID. *LCV231*.
Ficus xylophylla Wall. ex Miq., Ann. Mus. Bot. Lugduno-Batavi. 3: 286 (1867).
Specimen ID. *C96, LCV163*.
Ficus sp. 1.
Specimen ID. *C71, LCV173*.
Ficus sp. 2.
Specimen ID. *LCV160*.
Ficus sp. 3.
Specimen ID. *LCV311*.
Ficus sp. 4.
Specimen ID. *LCV174*.
Ficus sp. 5.
Specimen ID. *LCV178*.
Ficus sp. 6.

Specimen ID. *LCV203*.

Ficus sp. 7.

Specimen ID. *LCV293*.

Ficus sp. 8. Fig.16G & 16H.

Specimen ID. *LCV325, LCV373*.

Ficus sp. 9.

Specimen ID. *LCV339*.

Oxalidaceae

Dapania racemosa Korth., Ned. Kruidk. Arch. 3: 381 (1854). Fig.17A & 17B.

Specimen ID. *LCV117, LCV355*.

Notes. Epiphytic climber with adventitious roots; It has been known to be a liana growing on the ground (Veldkamp 1967, Ho et al. 2018), but collected plant was not attached to ground including roots, thus our observation represents the first record as an epiphyte; identified by using DNA sequencing.

Primulaceae

Embelia cf. *coriacea* Wall. ex A. DC., Trans. Linn. Soc. London 17(1): 135 (1834).

Specimen ID. *LCV87, LCV94, LCV240*.

Notes. Scandent shrub with pendent branches, lamina coriaceous; found on canopy humus; fairly common.

Embelia sp. 1. Fig.17C & 17D.

Specimen ID. *LCV273, LCV368*.

Notes. Creeping liana; found on fallen trees in 4 ha plot; rare.

Rubiaceae

Hydnophytum formicarum Jack, Trans. Linn. Soc. London 14(1): 124 (1823). Fig.17E & 17F.

Specimen ID. *LCV286*.

Notes. A myrmecophytic shrub; collected from 4 ha plot.

Myrmecodia tuberosa Jack, Trans. Linn. Soc. London 14: 123 (1823).

Specimen ID. *C7, LCV285*.

Psychotria sp. 1.

Specimen ID. *LCV253*.

Notes. Found on basal part of large tree or on decaying tree trunk.

Psychotria sp.2.

Specimen ID. *LCV254*.

Notes. Collected on basal part of large tree.

Psychotria sp. 3.

Specimen ID. *LCV294*.

Urticaceae

Poikilospermum suaveolens (Blume) Merr., Contr. Arnold Arbor. 8: 47 (1934). Fig.17G–17I.

Specimen ID. *LCV316*.

Notes. Myrmecophytic primary hemiepiphyte. Leaves thickly chartaceous to coriaceous.

Poikilospermum sp. 1.

Specimen ID. *LCV69*.

Notes. Myrmecophytic primary hemiepiphyte. Distinguished from *P. suaveolens* by its thinly chartaceous leaves; on lower part of tree trunks.

Procris pedunculata (J.R. Forst. & G. Forst.) Wedd., Prodr. [A.P. de Candolle] 16(1): 191 (1869).

Specimen ID. *C110*.

Notes. Semi-succulent herb; Rare.

Family Unknown

Unknown species 1.

Specimen ID. *LCV186*.

Notes. Shrub entirely glabrous for vegetative part; alternate pinnate leaves up to 50 cm long; collected from a large dead branch of tall *Shorea* tree in 8 ha plot.

Unknown species 2.

Specimen ID. *LCV398*.

Notes. Shrub with pendent slender branches; vegetative part entirely glabrous; leaves alternate, elliptic-lanceolate to lanceolate, thickly chartaceous; collected from riverine forest.

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Fig. 1. *Huperzia carinata* (Desv. ex Poir.) Trevis.: A & B, Habit; C, close-up photo showing stem and linear leaves. *Huperzia nummulariifolia* (Blume) Jermy: D, Habit. *Huperzia phlegmaria* (L.) Rothm.: E, Habit; F, strobili. Photos A & C, *LCV29*; B, *C75*; D, *LCV192*; E & F, *LCV233*.

Fig. 2. *Asplenium auriculatum* Sw.: A, Habit; B, fronds with rhizomes; C, rhizome. *Asplenium nidus* L.: D, Trapped litter in the rosette; E, habit; F, portion of sori. Photos A–C, *C119*; D–F, *LCV33*.

Fig. 3. *Davallia denticulata* (Burm.) Mett. & Kuhn: A, Habit (fertile frond); B, rhizome; C, sori. *Davallia solida* (Forst.) Sw.: D, Habit (sterile frond); E, rhizome. *Davallia* sp.: F, Sterile plant; G, sori. *Humata repens* (L.f.) Diels: H, Habit (sterile frond with rhizome); I, rhizome; J, portion of abaxial surface of frond. Photos A–C, no sample; D & E, *LCV16*; F, *LCV297*; G, *LCV205*; H–J, *LCV372*.

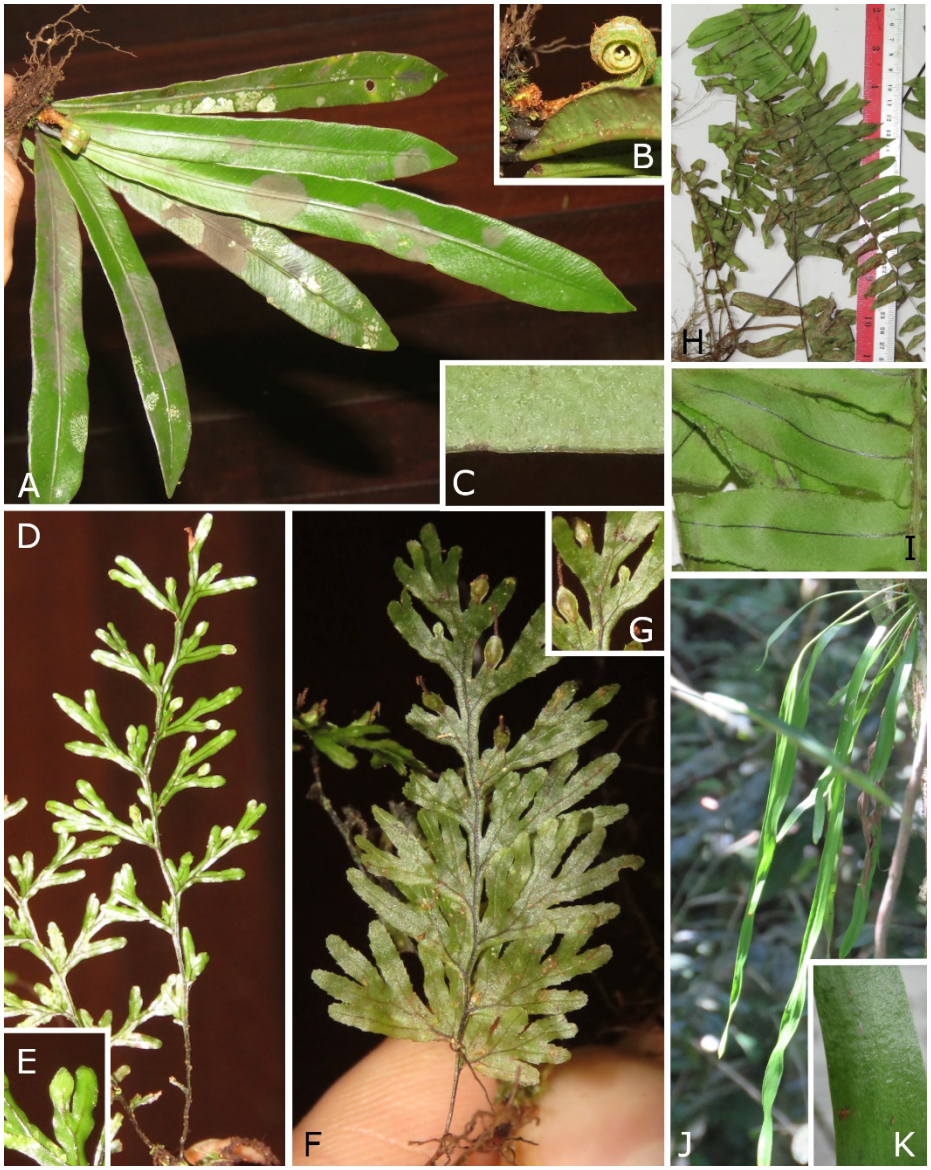

Fig. 4. *Elaphoglossum* sp.: A, Habit; B, young frond; C, portion of abaxial surface of frond. *Hymenophyllum* sp. 2.: D, Frond with sori; E, sorus. *Hymenophyllum* sp. 3.: F, Frond; G, sori. *Nephrolepis* sp.: H, Plant; I, abaxial surface of frond. *Ophioglossum pendulum* L.: J, Habit; K, portion of frond. Photos A–C, *LCV364*; D & E, *LCV365*; F & G, *LCV366*; H & I, *LCV292*; J, no sample; K, *LCV350*.

Fig. 5. *Drynaria quercifolia* (L.) J. Sm.: A, Habit; B, portion of rhizome with golden-brown hairs. *Drynaria sparsisora* (Desv.) T. Moore: C, Habit; D, rhizome. *Goniophlebium percussum* (Cav.) Wagner & Grether: E, Portion of adaxial surface of young frond; F, fertile frond; G, rhizome; H, sori. *Lecanopteris* sp.: I, Habit. Photos A & B, *LCV93*; C & D, *LCV9*; E–H, *LCV18*; I, no sample.

Fig. 6. *Platycerium coronarium* (O.F. Müll.) Desv.: A, Habit; B, internal surface of old leaf and roots. *Platycerium ridleyi* Christ: C, Habit. *Pyrrosia angustata* (Sw.) Ching: D, Habit; E, rhizome; F, sorus. *Haplopteris angustifolia* (Blume) E.H. Crane: G, Sterile plant; H, adaxial surface of frond; I, rhizome. Photos A, no sample; B, *C40*; C, no sample; D–F, *LCV103*; G–I, *LCV201*.

Fig. 7. *Amydrium medium* (Zoll. & Moritzi) Nicolson: A, Juvenile plant; B, inflorescence. *Rhaphidophora tenuis* Engl.: C, Habit of juvenile plant; D, abaxial surface of lamina. *Scindapsus beccarii* Engl.: E, Habit; F, leaf and infructescence; G, closeup photo showing matured infructescence. *Scindapsus coriaceus* Engl.: H, Habit; I, inflorescence. Photos A, *LCV333*; B, no sample; C & D, *LCV332*; E–G, *LCV199*; H & I, *LCV176*.

Fig. 8. *Bulbophyllum auratum* (Lindl.) Ridl.: A & B, Habit; C, inflorescence. *Bulbophyllum limbatum* Lindl.: D, Habit; E, flower. *Bulbophyllum vaginatum* Rchb. f.: F, Flowering plant; G, habit. *Coelogyne foerstermannii* Rchb. f.: H, Portion of inflorescence; I, habit. Photos A & B, *LCV45*; C, *LCV196*; D, *C41*; E, *LCV241*; F & G, *C57*; H, no sample; I, *LCV234*.

Fig. 9 *Dendrobium leonis* Rchb. f.: A, Habit. *Dendrobium pinifolium* Ridl.: B, Habit; C, flower. *Eria leiophylla* Lndl.: D, Flower. *Eria pannea* Lindl.: E, Habit; F, flower. *Phalaenopsis cornu-cervi* (Hasselt ex Hassk.) Blume & Rchb. f.: G, Habit of flowering plant; H, flower. Photos A, *LCV84*; B & C, *LCV230*; D, *LCV115*; E, *LCV40*; F, *C63*; G & H, no sample.

Fig. 10. *Benstonea* sp.: A, Habit. *Freycinetia* sp. 1: B, Habit of juvenile plant; C, adaxial surface of lamina. *Amomum roseisquamosum* Nagam. & S. Sakai: D, Habit; E, young inflorescence. Photos A, no sample; B & C, *LCV326*; D & E, *LCV223*.

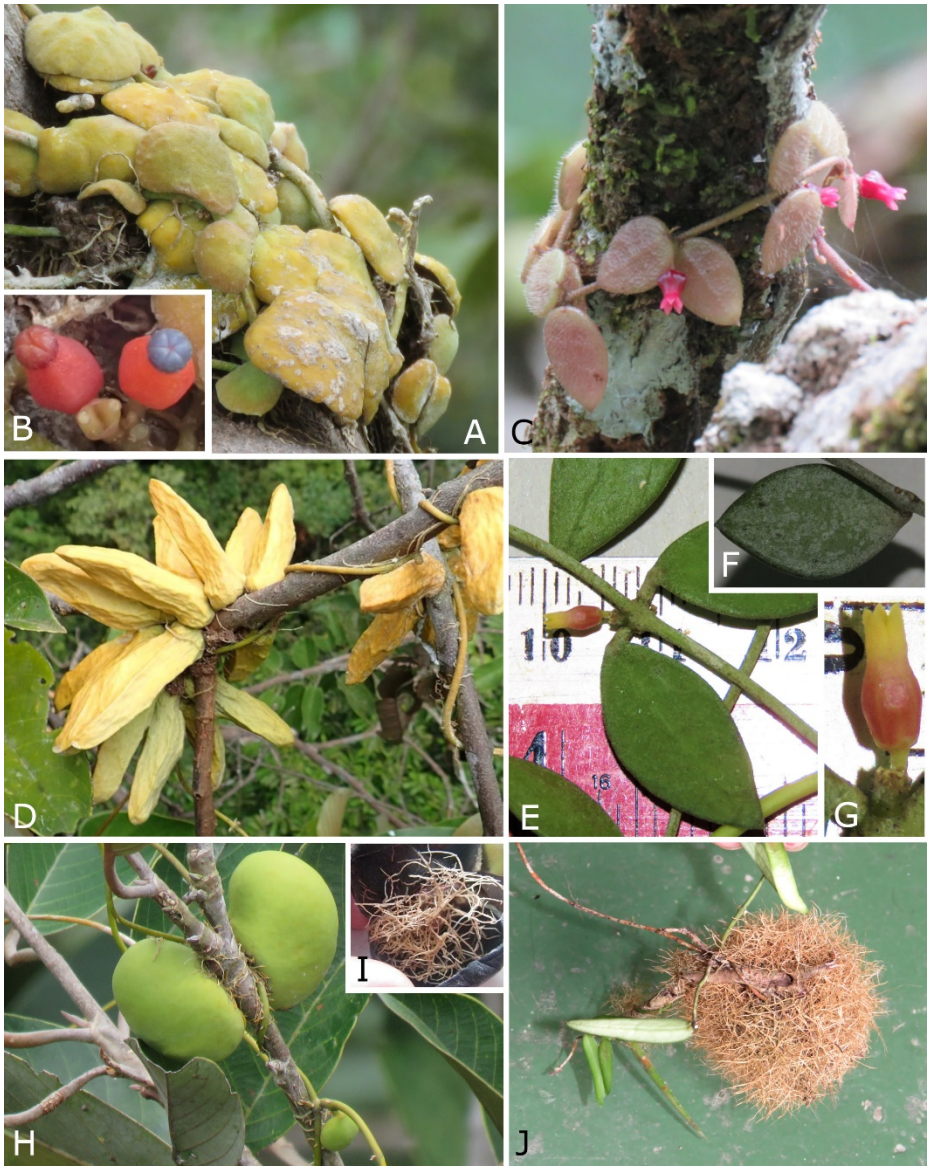

Fig. 11. *Dischidia cochleata* Blume: A, Habit; B, flowers. *Dischidia hirsuta* (Blume) Decne.: C, Habit of flowering plant. *Dischidia major* (Vahl) Merr.: D Habit. *Dischidia* sp. 2: E, Flowering plant; F, abaxial surface of lamina; G, flower. *Dischidia* sp. 3: H, Habit; I, cross section of domatia. *Dischidia* sp. 8.: J, Plant with clustered aerial roots. Photos A & B, *LCV259*; C, no sample; D, *LCV49*; E–G, *LCV291*; H & I, *C31*; J, *LCV318*.

Fig. 12. *Hoya lacunosa* Blume: A, Plant; B, young inflorescence. *Hoya mitrata* Kerr: C, Habit; D, base of lamina; E, domatia. *Hoya* cf. *sigillatis* T. Green: F, Habit; G, adaxial surface of lamina. Photos A & B, *LCV269*; C–E, *LCV386*; F & G, *LCV260*.

Fig. 13. *Schefflera littoralis* (Miq.) Harms.: A, Fruiting branch; B, stem; C, portion of inflorescence. *Vaccinium* sp.: D, Habit; E, young inflorescence; F, adaxial surface of lamina. Photos A & C, no sample; B, *LCV92*; D & E, no sample; F, *LCV32*.

Fig. 14. *Fagraea ceilanica* Thunb.: A, Habit; B, twig. *Fagraea ridleyi* King & Gamble: C, Fallen branch; D, fruit. *Aeschynanthus angustifolius* (Blume) Steud.: E, Habit of fruiting plant; F, branch; G, seeds. *Aeschynanthus tricolor* Hook.: H, Inflorescence; I, leafy branch. Photos A, no sample; B, *LCV353*; C, *LCV249-2*; D, *LCV301*; E–G, *LCV315*; H, *LCV337*; I, no sample.

Fig. 15. *Heteroblemma* sp.: A, Leafy twig. *Pachycentria constricta* Blume: B, Habit. *Pachycentria glauca* Triana: C, Fruiting branch; D, roots with tubers. *Pachycentria* sp. 1.: E, Leafy twig. *Plethiandra tomentosa* G. Kadereit: F, Leafy twig; G, flower buds. Photos A, *LCV352*; B, no sample; C & D, *LCV331*; E, no sample; F, no sample; G, *LCV400.*

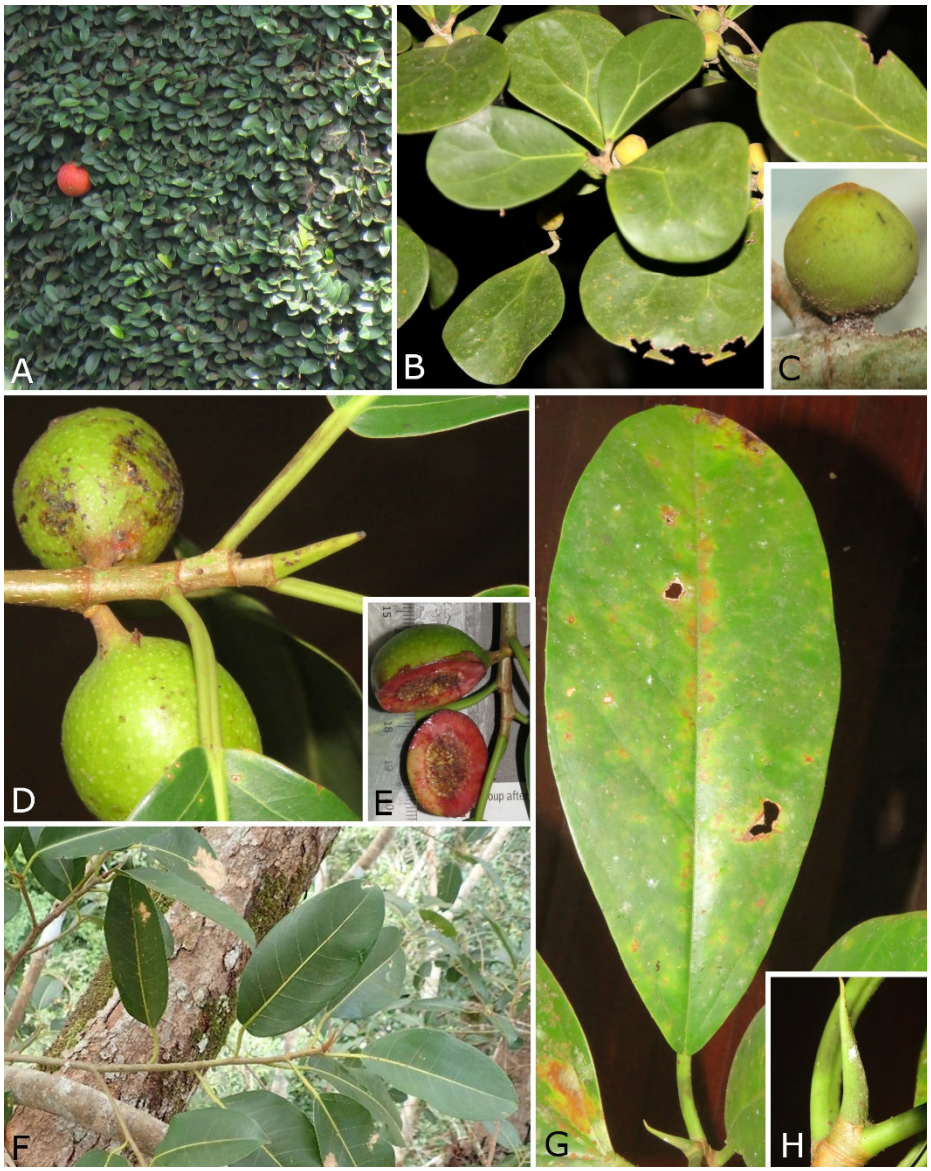

Fig. 16. *Ficus aurantiaca* Miq.: A, Fruiting plant. *Ficus deltoidea* Jack: B, Branch with syconia; C, syconium. *Ficus dubia* Wall. ex King: D, Branch with syconia; E, cross section of matured syconium; F, branch. *Ficus* sp. 8.: G, Leaf and shoot apex; H, terminal bud. Photos A, no sample; B, no sample; C, *LCV356*; D & E, *LCV397*; F, *LCV125*; G & H, *LCV373*.

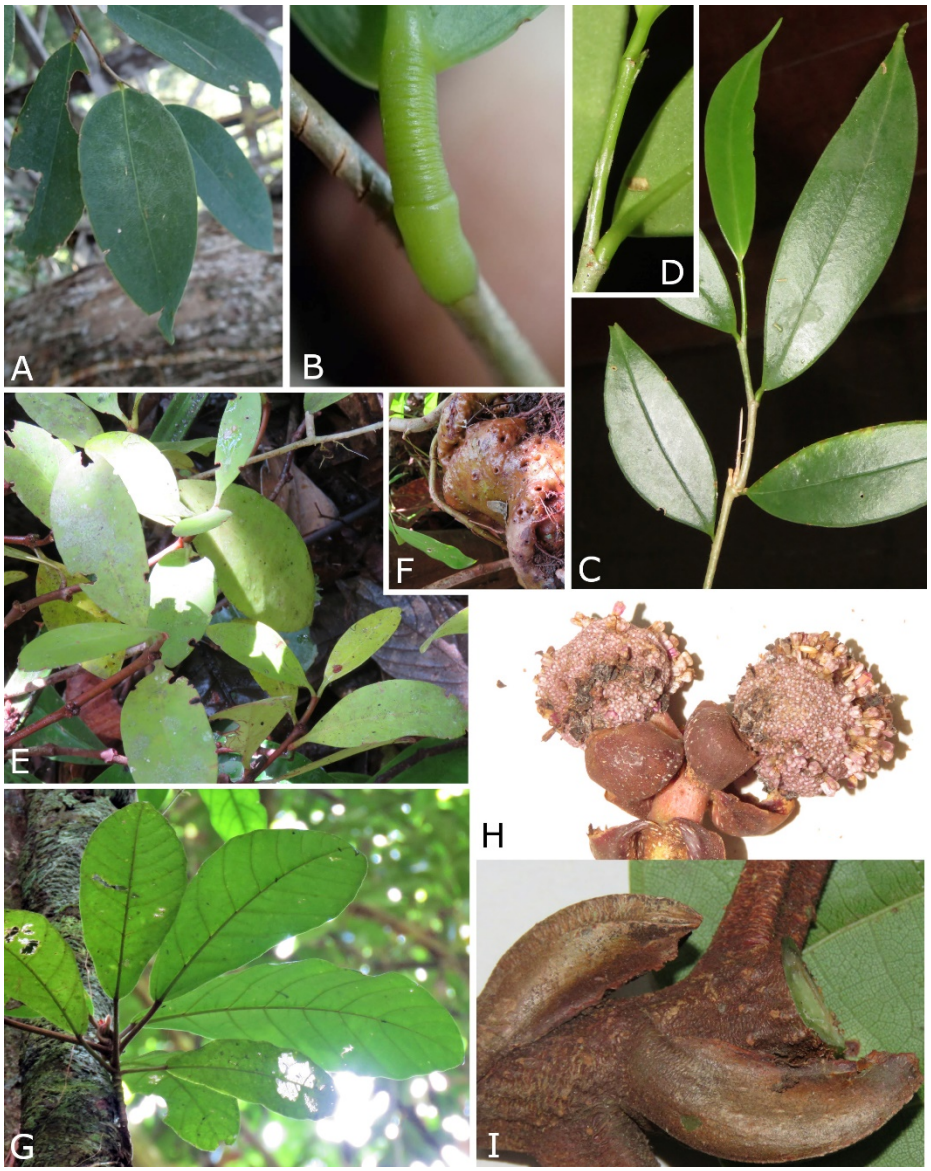

Fig. 17. *Dapania racemosa* Korth.: A, Leafy twig; B, abaxial side of petiole. *Embelia* sp. 1.: C, Leafy twig; D, closeup photo showing abaxial side of twig. *Hydnophytum formicarum* Jack: E, Leafy twigs; F, domatia at basal part of stems. *Poikilospermum suaveolens* (Blume) Merr.: G, Habit of juvenile plant; H, portion of inflorescence; I, stipules forming domatia. Photos A & B, *LCV117*; C & D, *LCV368*; E & F, *LCV286*; G, no sample; H & I, *LCV316*.

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